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METHODS OF ERADICATING BUCKTHORN (RHAMNUS) SUSCEPTIBLE TO CROWN RUST (PUCCINIA CORONATA) OF OATS[1]

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INTRODUCTION

Controlling a rust by the eradication of its alternate host is an old practice. Lind (*12*)[2] cites many examples of the extermination of the barberry bush in Europe during the early nineteenth century as a means of preventing damage by *Puccinia graminis* Pers. Although no definite record is available, the earliest barberry law is thought to have been passed in Rouen, France, in 1660. This is of unusual interest, for it was more than 200 years before De Bary (*2*) established the host relationship of *Berberis vulgaris* L. to *P. graminis*.

The eradication of *Rhamnus cathartica* L. to control *Puccinia coronata* Corda, the crown rust of oats and related grasses, was first suggested by Henning (*9*) in 1894. Definite recommendations for its eradication were made by him in 1912 (*10*). That the destruction of *R. cathartica* is effective in controlling crown rust of oats in the upper Mississippi Valley was shown by Dietz (*6*), when 520 rods of this shrub were grubbed from a 120-acre farm near Hinton, Iowa. Although it had been definitely shown that *R. cathartica* and *R. lanceolata* Pursh. were directly responsible for the frequent devastating outbreaks of crown rust in this section (*7*), the most opportune time and effective method of eradication had not been discovered.

Among the early reports on the use of chemicals as herbicides are those of Jones and Orton in 1897 (*11*), Dusserre in 1899 (*8*), and Bolley in 1900 and 1901 (*3*, *4*) and later, in 1908 (*5*). These investi-

[1] The investigations herein reported were conducted in cooperation with the section of botany and plant pathology of the Iowa Agricultural Experiment Station.

[2] Reference is made by italic numbers in parentheses to Literature Cited, p. 15.

gators confined the application of numerous chemicals to the leaves and stems of growing plants. In 1902 Potts (*13*) suggested the use of waste sulphuric acid on the roots of briers.

Rudolfs (*14*) reported the application of salt to the stumps of birch, cherry, dogwood, maple, and oak. From 2 to 2½ tons of salt to the acre, either broadcast or placed around the stumps, did not prevent later growth.

In 1925 Schulz and Thompson (*15*) reported arsenic as fatal to *Berberis vulgaris* when applied to the roots. Its toxicity to animals, however, makes its use dangerous. A year later Thompson and Robbins (*16*) reported on experiments involving the use of 37 different chemicals in the eradication of the common barberry. They concluded that salt, kerosene, and sodium arsenite were the most effective.

Åslander (*1*) destroyed mustard plants (*Brassica arvensis*) in 24 hours with a 5 per cent solution of iron sulphate applied at the rate of 1 gram to a square decimeter when the relative humidity was 100 per cent. A solution of 1 to 2 per cent sulphuric acid was effective in killing mustard plants. This acid was most effective in a relatively dry atmosphere.

METHODS AND MATERIALS

The experiments on the eradication of the alternate hosts of crown rust herein described were carried on in Cass, Decatur, Lucas, Marshall, and Pottawattamie Counties, Iowa, and in Nodaway County, Mo., in order to determine the most effective and economical methods of destroying these shrubs. The nine mechanical and chemical methods employed in the experiments are described as follows:

1. Grubbing. The entire plant, including crown and roots, was removed from the ground.
2. Felling. The trunk of the buckthorn was cut off a few inches above the crown. The latter remained in the soil, attached to the roots.
3. Removal of root crown. Sufficient soil was removed to permit cutting a few inches below the crown. The latter was then removed, but all roots remained in the ground. (The crown is the portion of the plant forming the union of the stems and roots.)
4. Girdling. A 4-inch band of bark and cambium layer was removed from the trunk at a point a few inches above the level of the ground.
5. Salting. The soil around the crown was removed to form a small basin in which a definite quantity of salt, varying from 2½ to 23 pounds, was placed.
6. Kerosening. A basin as described in the salting method was formed; from 1 to 4 quarts of kerosene was poured on the crown and adjacent roots.
7. Crown removal and salting. The crown was removed as in method No. 3 and a definite quantity of salt was placed on the remaining roots.
8. Felling and salting. The trunk was cut off a few inches above the ground, and a definite quantity of salt was placed around the crown.
9. Felling and kerosening. The trunk was cut off a few inches above the ground, and the crown was completely covered with a definite quantity of kerosene. A small quantity of soil was removed from around the crown to allow the kerosene to make contact over the entire crown.

Two hundred and fifty-eight bushes of *Rhamnus lanceolata* and 22 of *R. cathartica* were treated in 1926 and kept under observation for 18 months. In 1927, 175 bushes of *R. lanceolata* were treated and observed for 7 months. These bushes varied in size from 1 to 105 square inches in area of cross section a few inches above the crown. Detailed records of the condition of each shrub were made

at approximately 30-day intervals during the growing season. Shrubs were recorded as " alive " until the bark and cambium of the lower trunk stopped functioning.

To determine the relation of time of year to the effectiveness of treatment, *R. lanceolata* was treated on March 19, July 22, and August 24, 1926, and on March 21 and 22, 1927. Commercial kerosene and common rock salt were used in these studies.

For convenience, the writers have separated the *R. lanceolata* plants into eight groups, according to area of the cross section of the stems near the ground line. These groups are as follows (measurements in square inches): 1–5, 6–15, 16–25, 26–35, 36–45, 46–65, 66–85, and 86–105.

The bushes of *R. cathartica* were much larger than those of *R. lanceolata* and accordingly were divided into the following four groups: 21–40, 41–80, 81–120, and 121–420 square inches.

ERADICATION OF RHAMNUS SPECIES

In those sections of the United States where urediniospores do not overwinter, the rôle of Rhamnus species in the dissemination of crown rust is determined by at least five factors, namely, the susceptibility and geographic distribution of the gramineous hosts, the environmental factors, and the prevalence and distribution of the susceptible alternate hosts. This bulletin deals with the last two factors, together with the best methods of eradicating these alternate hosts.

ABUNDANCE AND DISTRIBUTION OF SUSCEPTIBLE RHAMNUS SPECIES

The relative response of 33 species of Rhamnus to *Puccinia coronata avenae* is now known. Twelve of the nineteen varieties of species of Rhamnus susceptible to this physiologic variety of crown rust occur in the United States. *Rhamnus alpina* L., *R. crenulata* rust occur in the United States. *Rhamnus alpina* L., *R. crenulata* Schneid.. *R. rupestris* Scop., and *R. tinctoria* Waldst. and Kit. are susceptible, but so far as the writers know they are found only in experimental grounds in this country. It should be emphasized here that care should be exercised in the artificial planting of the above-named species. Of the susceptible species now known and more or less widely distributed in this country, *Rhamnus alnifolia* L'Her., *R. californica* Ech., *R. californica tomentella* Brewer and Watson, *R. caroliniana* Walt., *R. crocea* Nutt., *R. ilicifolia* Kellogg, *R. lanceolata* Pursh., *R. pachyphylla* Heller, *R. pinetorum* Heller, *R. rubra* Greene, and *R. smithii* Greene are native, while *R. cathartica* L., an introduced species, has escaped and become naturalized in many sections in Illinois, Iowa, Montana, and Wisconsin.

The susceptibility of certain Rhamnus species having been established, their importance in disseminating crown rust depends upon their number and distribution in the main oat-growing regions outside the area in which *Puccinia coronata* commonly overwinters in the uredinial stage.

A survey of the locations and numbers of *Rhamnus cathartica* in the upper Mississippi Valley was started in 1923, through the co-

operation of the 13 State leaders of barberry eradication. During the period from 1923 to 1926, inclusive, 1,763 locations, containing 304,568 bushes, were reported by them and their associates. (Table 1.) There were about as many bushes in the country as in the city. By far the largest number of bushes are in the form of cultivated hedges. However, there are a few areas in northern Illinois, southern Wisconsin, eastern Iowa, and northwestern Montana where the bushes have escaped cultivation and occur in considerable numbers. Figure 1 shows that *R. cathartica* is distributed over the northern

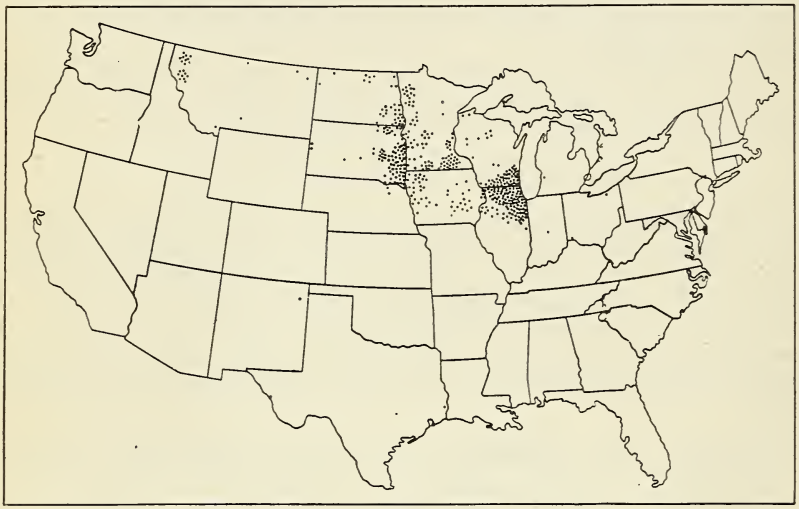

FIGURE 1.—Map showing distribution of *Rhamnus cathartica* in the upper Mississippi Valley as reported during the period from 1923 to 1926, inclusive. Each dot represents 500 bushes

oat-growing section in sufficient numbers to cause severe crown-rust damage under favorable weather conditions.

TABLE 1.—*Summary of location and numbers of bushes of Rhamnus cathartica reported in the States of the upper Mississippi Valley, 1923–1926*

State	City locations	City bushes	Country locations	Country bushes	Total locations	Total bushes
Illinois	65	48,125	128	49,750	193	97,875
Indiana	1	6	3	151	4	157
Iowa	110	13,185	77	11,162	187	24,347
Michigan			3	107	3	107
Minnesota	405	21,700	249	24,421	654	46,121
Montana	38	2,401	2	10,000	40	12,401
Nebraska	7	763	4	267	11	1,030
North Dakota	79	6,838	92	10,807	171	17,645
Ohio	4	26	3	514	7	540
South Dakota	295	47,369	74	21,036	369	68,405
Wisconsin	16	1,673	108	34,267	124	35,940
Total	1,020	142,086	743	162,482	1,763	304,568

Rhamnus lanceolata, a native species of buckthorn, is responsible for local epidemics of crown rust in many parts of southern Iowa and northern Missouri, as well as in adjoining States. While no

accurate list of the locations of *R. lanceolata* has been compiled, it has been possible to estimate the relative occurrence of this shrub, based on actual observation and on information furnished by the curators of herbariums in the different States. The data are given in Table 2.

TABLE 2.—*Estimated distribution and numbers of Rhamnus lanceolata in the United States*

State	Number of bushes	State	Number of bushes	State	Number of bushes
Alabama	2,000	Maryland	1,000	Texas	10,000
Arkansas	6,000	Missouri	70,000	Virginia	5,000
Illinois	10,000	Nebraska	15,000	West Virginia	5,000
Indiana	5,000	Ohio	5,000		
Iowa	105,000	Oklahoma	10,000	Total	284,000
Kansas	10,000	Pennsylvania	5,000		
Kentucky	5,000	Tennessee	15,000		

Two hundred and eighty-four thousand bushes of this species have been estimated as occurring in 17 States. (Fig. 2.) It is found

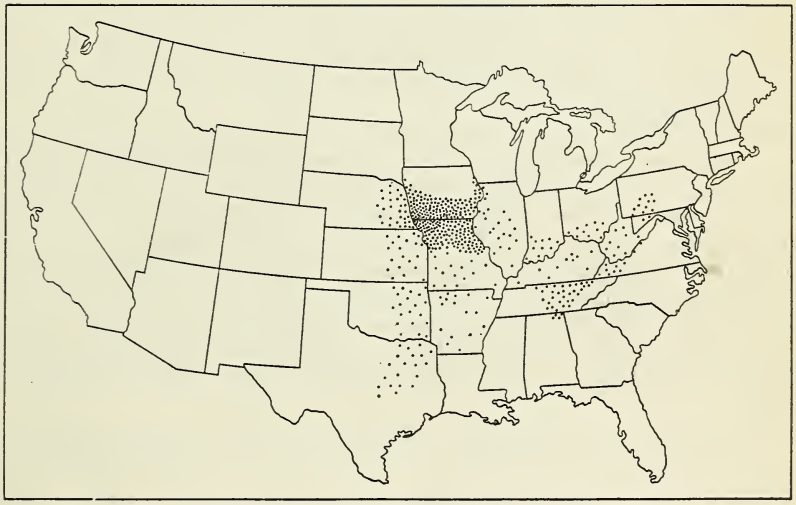

FIGURE 2.—Map showing distribution of *Rhamnus lanceolata* in the United States. Each dot represents an estimate of 500 bushes

most commonly in southwestern Iowa and northwestern Missouri. Its northern limit is the central parts of Iowa, Illinois, and Indiana and the southern parts of Ohio and Pennsylvania, although along the rivers it may be found somewhat north of this line. It is commonly found as far south as Alabama and Texas, although in the Southern States it is largely replaced by *R. caroliniana.*

Rhamnus lanceolata probably is not an important factor in crown-rust dissemination in the winter-oat area, as the urediniospores overwinter throughout most of this area. The approximate northern limit of winter survival of urediniospores in the lower Mississippi Valley does not coincide with the northern limit of the winter-oat area. North of the limit of winter survival there is a gradual

northward spread of urediniospores in the spring, especially on volunteer oats. North of the overwintering area there is a strip of country in which *R. lanceolata* usually does not become infected. Urediniospores of crown rust spread into this area, however, from the overwintering section to the south and the section to the north in which primary infection depends on aeciospores. In the northern half of the oat-growing section Rhamnus species become infected and cause the annual primary infection on oats from which a secondary spread occurs.

Rhamnus alnifolia, primarily a northern species, reaching its southern limits in Illinois, northeastern Iowa, and Nebraska, is native to the main oat-growing region of this country. Although normal aecia have been produced on this species when exposed to infection with teliospores from *Avena sativa*, it is extremely resistant to *Puccinia coronata avenae*. It is susceptible to *P. coronata calamagrostidis*, and, owing to its habitat in swamps, it functions mostly as an alternate host to the physiologic variety of crown rust peculiar to *Calamagrostis canadensis*. It plays little part in the dissemination of crown rust of oats.

Rhamnus californica, *R. californica tomentella*, and *R. caroliniana* may readily function as alternate hosts of crown rust, but they occur where crown-rust urediniospores overwinter. The susceptible species, *R. crocea*, *R. ilicifolia*, *R. pachyphylla*, *R. pinetorum*, *R. rubra*, and *R. smithii*, are confined to regions where the oat crop is not important commercially.

The chronologic sequence of appearance of infection on *R. cathartica* and *R. lanceolata* and on oats, in Iowa, is further evidence of the importance of the rôle these two species play in the dissemination of crown rust. From the data of Table 3 it is evident that during the 12 years, 1916 to 1927, inclusive, aecial infection appeared in Iowa on *R. cathartica* or *R. lanceolata* prior to the appearance of the uredinial stage on oats. Furthermore, the initial infection on oats in Iowa has been directly traceable to aeciospores during each of the 11 years, 1916 to 1926, inclusive. What has happened in Iowa probably is typical of the other States of the upper Mississippi Valley.

TABLE 3.—*Date of first appearance of crown-rust aecia on Rhamnus cathartica and R. lanceolata and of uredinia on Avena sativa in Iowa for each year, 1916–1927*

Host	Stage in life cycle	First appearance in—					
		1916	1917	1918	1919	1920	1921
Rhamnus cathartica	Aecial	May 7	June 30	Apr. 30	May 26	May 15	May 16
Rhamnus lanceolata	Aecial	May 22	----------	June 6	May 15	May 20	Do.
Avena sativa	Uredinial	June 2	July 6	July 6	June 6	June 12	May 22

Host	Stage in life cycle	First appearance in—					
		1922	1923	1924	1925	1926	1927
Rhamnus carthartica	Aecial	May 14	May 21	May 28	Apr. 23	May 11	May 18
Rhamnus lanceolata	Aecial	May 21	May 23	May 7	Apr. 27	May 4	Apr. 27
Avena sativa	Uredinial	June 14	June 16	June 16	June 6	June 11	May 28

The year 1927 was the first since 1916 when a spread of crown rust occurred which could not be traced directly either to *R. cathartica* or *R. lanceolata*. The latter was heavily infected with *Puccinia coronata avenae* in southwestern Iowa during May, 1927, but the subsequent lack of moisture prevented the sporidia from infecting the adjacent oats. Such infection of the oat crop as did develop in 1927 evidently originated from urediniospores from the Southern States, where overwintering occurs on winter oats. The extremely light infection of oats with crown rust in Iowa in 1926, resulting in the formation of few teliospores, may partly explain the light aecial infection on *R. cathartica* in 1927.

ERADICATION OF RHAMNUS LANCEOLATA

To determine the best methods of eradicating *Rhamnus lanceolata*, 433 bushes were used, varying in size from 1 to 105 square inches in cross section, measured just above the crown. The following six methods were employed: (1) Application of 2½ to 23 pounds of salt to the standing bush; (2) application of 1 pint to 4 quarts of kerosene to the standing bush; (3) removal of the crown of the bush with no chemical treatment; (4) removal of the crown followed by application of 2½ to 20 pounds of salt to the root remnants in the ground; (5) cutting off the bush above the crown, followed by applications of 2½ to 20 pounds of salt; (6) applications of one-half to 4 pints of kerosene to the crown and roots remaining in the ground. The effects of seasonal conditions on the different treatments also were studied.

ERADICATION WITH SALT

One hundred and thirty-five bushes of *Rhamnus lanceolata*, varying in size from 1 to 105 square inches in cross section of the main stems just above the crown, were treated with 2½ to 23 pounds of salt to the bush. Data presenting the results are given in Table 4. It is evident that 2½ pounds of salt is not 100 per cent effective even on the smallest bushes, as 2 of the 21 bushes so treated were not killed. Five pounds of salt killed the 9 bushes measuring 5 square inches or less in cross section, while 10 and 15 pounds killed bushes measuring 25 square inches or less in cross section. The results obtained from applications of 20 pounds of salt to the bush are somewhat erratic, this quantity killing but 2 out of 3 bushes measuring 26 to 35 square inches in cross section. The 1 bush recorded as living was nearly dead and probably would have died later. Twenty-three pounds of salt killed all 6 bushes to which this quantity was applied, the bushes varying in size from 1 to 65 square inches in cross section.

TABLE 4.—*Number of Rhamnus lanceolata bushes of different sizes treated with salt and the number killed by each treatment*

Salt per bush (pounds)	Number of bushes with stems of size indicated in square inches of cross section															
	1–5		6–15		16–25		26–35		36–45		46–65		66–85		86–105	
	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed
2.5	21	19	8	2	5	0	1	1	1	0	-----	-----	-----	-----	1	0
5	9	9	11	7	1	1	4	1	1	0	2	0	1	0	-----	-----
10	3	3	10	10	4	4	4	2	5	3	2	0	1	1	-----	-----
15	2	2	3	3	4	4	3	1	3	1	2	0	1	1	-----	-----
20	2	2	1	1	4	4	3	2	3	2	2	2	-----	-----	1	0
23	2	2	1	1	1	1	-----	-----	1	1	1	1	-----	-----	-----	-----

ERADICATION WITH KEROSENE

Kerosene, varying in quantities from one-half to 4 quarts to the bush, was applied to the crowns of 105 standing bushes varying in cross section from 1 to 105 square inches. The results are presented in Table 5. One pint of kerosene killed all 14 bushes to which this quantity was applied, the bushes measuring from 1 to 35 square inches in cross section. A 1-quart application killed 35 out of 36 bushes of similar size. The 1 surviving bush was one of the 6 to 15 square-inch class. Its survival may be attributed to seasonal effect, to be considered in detail later. All bushes 45 inches or less in cross section were killed by an application of 2 quarts. Similar results were obtained when 3 quarts were used. Twelve of 13 bushes 65 square inches or less in cross section were killed by an application of 4 quarts of kerosene. Such a bush is shown in Figure 3. Kerosene probably was not uniformly applied to the bush in the 26 to 35 square-inch group, recorded as living, one limb remaining alive. Three bushes measuring from 86 to 105 square inches were treated with 2, 3, or 4 quarts of kerosene, respectively. Many of the bushes remaining alive at the close of these experiments were badly damaged and may die.

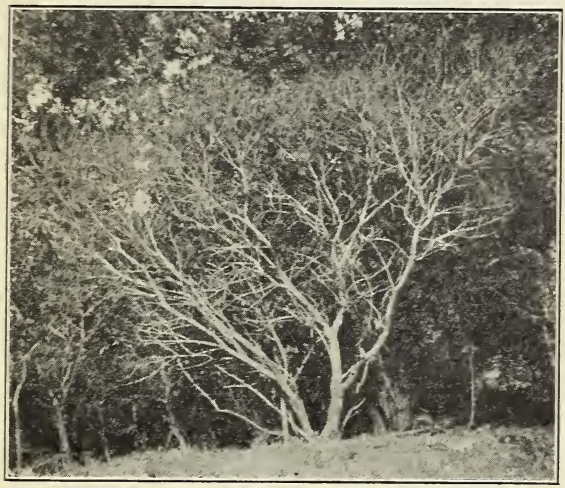

FIGURE 3.—A bush of *Rhamnus lanceolata* whose area in cross section was 28 square inches, treated at the base with 4 quarts of kerosene, at Griswold, Iowa, March 22. Photographed July 12, 1927

TABLE 5.—*Number of Rhamnus lanceolata bushes treated and killed by kerosene*

Kerosene per bush (quarts)	Number of bushes with stems of size indicated in square inches of cross section													
	1–5		6–15		16–25		26–35		36–45		46–65		86–105	
	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed
0.5	6	6	6	6	1	1	1	1	------	------	------	------	------	------
1	17	17	12	11	5	5	2	2	------	------	------	------	------	------
2	3	3	9	9	4	4	4	4	3	3	1	0	1	0
3	------	------	6	6	3	3	3	3	3	3	------	------	1	0
4	------	------	4	4	2	2	5	4	1	1	1	1	1	1

ERADICATION BY REMOVAL OF CROWN

To determine the relative effectiveness of removing the crown as a method of eradication, 67 bushes of *Rhamnus lanceolata*, varying in size from 1 to 65 square inches in cross section, were thus treated

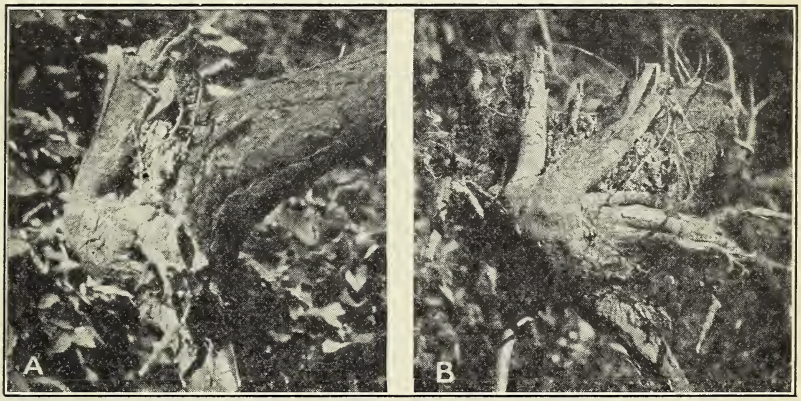

FIGURE 4.—A, Lateral view of the base of a *Rhamnus lanceolata* bush, showing the absence of a taproot; B, ventral view of same root system, showing arrangement of lateral roots

with salt, varying from 2½ to 20 pounds per bush, applied to the portion of the plant remaining in the soil. As previously stated, the removal of the crown consisted of severing all the roots just at the base of the main stem. Figure 4, A and B, shows two views of this stem and root system. The data in Table 6 show that all 67 bushes so treated were killed.

The fact that all bushes with crowns removed failed to survive, regardless of the quantity of salt applied to their roots, led to a comparison of the effectiveness of the removal of the crown with that of the removal of the crown plus the addition of salt. The crowns were removed from 15 bushes, 6 of which measured from 1 to 5 square inches in cross section just above the crown, 8 measured from 6 to 15 square inches, and 1 as much as 16 to 25 square inches. This treatment was 100 per cent effective.

TABLE 6.—*Number of Rhamnus lanceolata bushes treated and killed by removal of the crown combined with the application of salt*

Salt per bush (pounds)	Number of bushes with stems of size indicated in square inches of cross section									
	1–5		6–15		16–25		26–35		46–65	
	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed	Treated	Killed
2.5	3	3	5	5	4	4	2	2	1	1
5	13	13	12	12	3	3	2	2	----	----
7.5	----	----	2	2	----	----	----	----	----	----
10	3	3	1	1	5	5	2	2	----	----
15	1	1	3	3	2	2	----	----	----	----
20	----	----	----	----	1	1	1	1	1	1

ERADICATION BY FELLING

In order to determine the effectiveness of felling, four bushes measuring from 1 to 15 square inches in cross section were chopped down. All sprouted and remained alive. As this method alone was ineffective, it was combined with an application of 2½ to 20 pounds of salt to the bush. This combination killed all the 25 bushes so treated, which ranged from 1 to 35 square inches in cross-section area.

Fifty-four bushes varying from 1 to 45 square inches in cross-section area were felled, and each was treated with ½ to 4 pints of kerosene in August. Twenty bushes whose areas in cross section were 1 to 15 square inches were treated with one-half pint of kerosene, the treatment resulting in the death of 18 bushes. One pint of kerosene was applied to each of 20 bushes varying from 1 to 25 square inches in cross-section area, and 2 pints were applied to 13 bushes from 1 to 45 square inches, resulting in the death of all of the 33 bushes. Four pints of kerosene killed one bush 25 square inches in cross section.

Nineteen bushes from 1 to 15 square inches in cross-section area that received no further treatment after felling were sprouting profusely 250 days after treatment. It should be stated that apparently it is necessary to apply kerosene directly to the crown in quantities sufficient to cover it in order to cause death.

If the roots remaining in the soil produced sprouts when mechanical means of eradication were employed, it would be necessary to grub out the entire root system of the plant. Two plants measuring from 6 to 15 square inches in cross section were thus removed. This method proved effective but too laborious.

Girdling by removing a band of bark and cambium 6 inches wide just above the crown on each of the main stems was tried on five bushes measuring from 1 to 25 square inches in cross section. Although effective on all except one bush of the 16 to 25 square-inch class, it is a doubtful practice, because the bushes sprouted profusely from the crown. These sprouts were alive in the fall, but only one bush survived the winter. It is possible, however, that the sprouts may serve as a means of renewing the bush.

Two untreated bushes, each 2 feet from a treated bush, were observed in order to determine the effect of leaching. When 20 pounds of salt was used, the untreated bush of the 1 to 5 square-inch group

was killed, but when only 2½ pounds of salt was applied, the untreated bush of the 6 to 15 square-inch group remained alive.

RELATION OF TIME OF TREATMENT TO RATE OF KILLING OF RHAMNUS LANCEOLATA

Although the relative effectiveness of various quantities of salt and kerosene has been considered in the foregoing pages, it is impor-

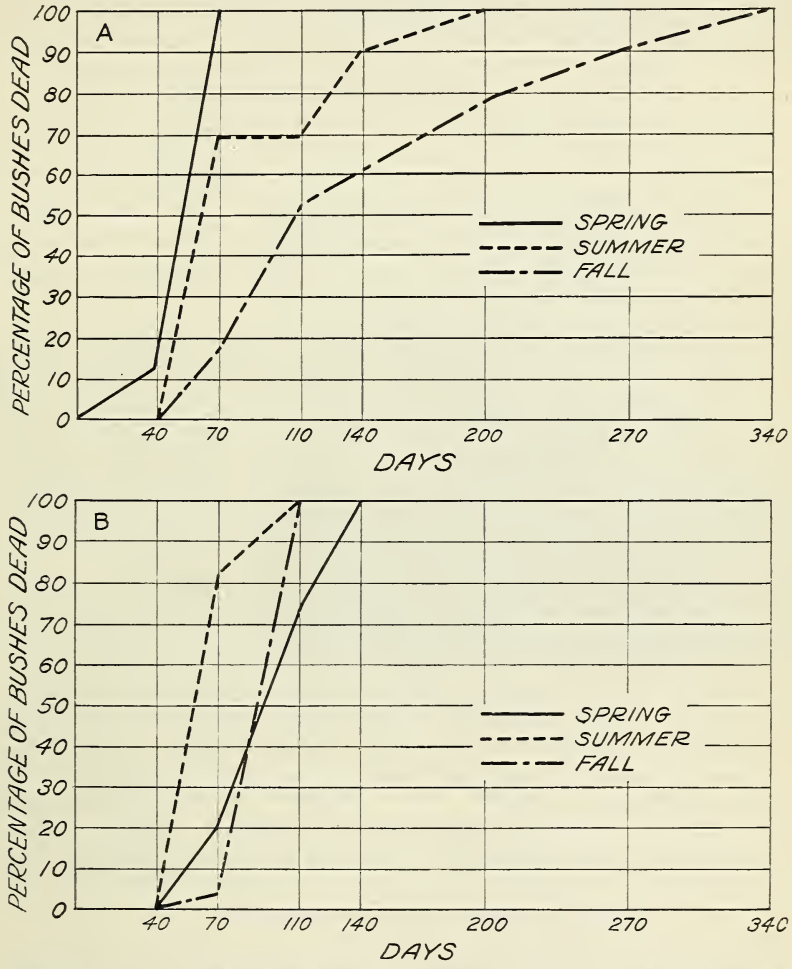

FIGURE 5.—(A) A graphic comparison of the rates of killing *Rhamnus lanceolata* by salt when applied in the spring, summer, or fall; (B) a graphic comparison of the rates of killing *R. lanceolata* by kerosene when applied in the spring, summer, or fall

tant also to consider the relative rates of completely effective action of salt and kerosene, respectively, applied in any given season of the year.

A total of 76 bushes, under observation for 18 months and varying in size from 1 to 35 square inches in area of cross section, were killed by 2½ to 20 pounds of salt. The data are presented in Table 7 and Figure 5, A. Of the 24 bushes treated in March, 3 died at the end

of 40 days and none remained alive after 70 days. Twenty-nine bushes were treated in July, and none were dead at the end of 40 days; 200 days elapsed before all had been killed. Only 4 of the 23 bushes treated in August had died at the end of 70 days, and it required 340 days to kill all of them.

TABLE 7.—*Relative effective lethal rates of salt and kerosene when applied to Rhamnus lanceolata in spring, summer, or late summer, as shown by numbers of bushes killed at end of periods stated*

Treatment	Season of treatment	Number of bushes killed in the specified number of days after treatment						
		40	70	110	140	200	270	340
Salt	Spring	3	21					
	Summer		20		6	3		
	Late summer		4	8	2	4	3	2
Kerosene	Spring		9	24	12			
	Summer		9	2				
	Late summer		1	29				

By using kerosene in quantities varying from 1 pint to 4 quarts, 86 bushes, varying in size from 1 to 35 square inches in cross section, were killed. The data are presented in Table 7 and Figure 5, B. The 45 bushes treated in March were all alive at the end of 40 days, and only 9, or one-fifth, were dead at the end of 70 days. A total of 140 days was required to kill all 45 bushes. Nine out of the 11 bushes treated in July were dead at the end of 70 days, while but 1 of the 30 bushes treated in August had died at the end of the 70-day period.

As a means of comparing the relative rates of lethal effectiveness of salt and kerosene, the daily mean for the period from the time of treatment until killing resulted was determined for those bushes treated in March, July, and August with each chemical, respectively. The bushes treated with salt in March died in 66 days on an average, those treated in July in 98 days, and those in August in 162 days. It required an average of 110 days to kill the bushes treated with kerosene in March, 77 days for those treated in July, and 109 days for those treated in August. It is evident that salt has a rapidly decreasing lethal rate from spring to late summer. When kerosene was used, the bushes treated in July died most rapidly, while those treated in March and August died at a slower but similar rate.

ERADICATION OF RHAMNUS CATHARTICA

Although it is probable that *Rhamnus cathartica* and *R. lanceolata* may be eradicated by the same methods, 22 bushes of the former were treated by three different methods. These bushes varied from 20 to 320 square inches in cross-section area. One untreated bush had an area of 420 square inches. Four standing bushes, treated with 10 or 15 pounds of salt, were killed. Ten bushes were killed by removing the crowns and then applying salt at the following rates: 10 pounds to each of 4, 15 pounds to each of 2, and 20 pounds to each of 4 bushes. When the crowns of 8 bushes were removed and no further treatment given, all were killed. The untreated bush left as a control remained alive throughout these experiments.

In 1922 a 520-rod hedge of *R. cathartica*, varying in height from 16 to 20 feet, was partly grubbed and partly pulled out by means of a tractor. The latter method left so much soil on the roots that bushes removed in the fall of 1921 as well as those in the following spring produced normal leaves and were severely infected with crown rust in 1922. It was necessary to remove the soil from the roots in order to kill the bushes. Although the method of removing these bushes with a tractor was not entirely satisfactory, no sprouts appeared from the roots broken from the bushes and remaining in the soil.

DISCUSSION

Although relatively little is known of the action of chemicals on plants, the symptoms manifested by chemically treated plants are striking. Kerosene, applied to *Rhamnus lanceolata* in the spring in quantities sufficient to kill, causes a general yellowing of the leaves after about 70 days. This condition is followed by a general wilting of the leaves over the entire plant, with death resulting in 110 to 140 days. Bushes treated with kerosene in midsummer, when in full leaf, were badly wilted in 40 days and usually dead by the end of 70 days. The effect of treating with kerosene in the fall was similar to that in the spring treatments.

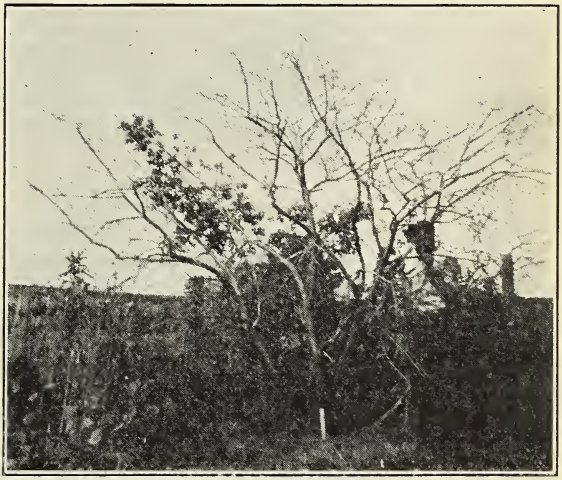

FIGURE 6.—A bush of *Rhamnus lanceolata*, the cross-section area of which was 28 square inches, treated with 15 pounds of salt. The result of insufficient salting is shown by the single living branch

Salt in lethal doses, applied to bushes in the spring just as the buds were swelling, prevented the leaves from unfolding. The action of salt, however, is dependent upon precipitation. This chemical had little effect until sufficient rain had fallen to dissolve it. Its action was much quicker in the spring than was that of kerosene, and death of the bushes resulted in 40 to 70 days. There was no basal sprouting of bushes treated in the spring, while those treated in midsummer or fall often sprouted profusely. The general effect of the salt was a drying of the leaves with subsequent defoliation, while kerosene caused a wilting of the leaves without subsequent defoliation. Insufficient applications of salt often killed a portion of the bush, while the remainder developed normally. (Fig. 6.) Insufficient salting in the fall often caused complete defoliation. In the following spring, profuse basal sprouting and an apparently normal foliation occurred, resulting in a complete recovery from the effects of the salt.

A consideration of the comparative cost of kerosene and salt shows no advantage for the latter. However, if eradication is attempted in the spring of the year, salt applied in quantities sufficient to kill will prevent foliation and subsequent aecial infection; while the bushes treated with kerosene in the spring and killed later in the growing season will develop an abundance of aecia under favorable growth conditions. As a method of eradication, removal of the crown was cheapest and most effective but entailed considerable manual labor. In locations where washing or erosion may take place this method is far superior to the use of either kerosene or salt. Felling, followed by light applications of salt or kerosene, is a cheap and effective method but entails more manual labor than does the use of either chemical alone.

It is evident from Table 7 that salt as a means of eradication may be used most advantageously in the spring because of its quicker action, while kerosene is preferable for summer application.

Although detailed experiments were not carried on with *Rhamnus cathartica*, it is probable, in the light of the effect of salt on this bush, that its response to eradication methods will be similar to those of *R. lanceolata*.

SUMMARY

Twelve of the nineteen species of Rhamnus, known to be susceptible to crown rust of oats, are found in the United States. *Rhamnus alnifolia*, *R. cathartica*, and *R. lanceolata* occur in the sections of the main oat-growing area in which urediniospores do not overwinter, and the last two have been instrumental in starting the initial infection of crown rust of oats each spring during 11 of the 12 years 1916 to 1927.

In a partial survey for *R. cathartica*, 304,568 bushes were located in the upper Mississippi Valley. For the middle and lower portions of the Mississippi Valley the number of bushes of *R. lanceolata* was estimated at 284,000.

One hundred and thirty-five bushes of *R. lanceolata*, varying in size from 1 to 105 square inches in cross-section area, were treated with 2½ to 23 pounds of salt to the bush. Quantities of salt required to kill the bushes of the various sizes are as follows: Five pounds for bushes varying from 1 to 5 square inches in cross section; 10 pounds for those ranging from 6 to 15 square inches; 15 pounds for those measuring from 16 to 25 square inches; 20 pounds for those measuring from 26 to 45 square inches; and 25 pounds for all larger sizes.

Kerosene, varying in quantities from one-half to 4 quarts, was applied to the crowns of 105 standing bushes whose areas in cross section varied from 1 to 105 square inches. One quart was sufficient to kill the bushes of the 1 to 5 square-inch group, 2 quarts were fatal to all bushes of the 6 to 15 square-inch group, 3 quarts killed all bushes measuring from 16 to 35 square inches in cross section, 4 quarts killed all bushes varying from 36 to 45 square inches, and 5 quarts were sufficient for all larger sizes.

Sixty-seven bushes of *Rhamnus lanceolata* were eradicated by removing the crown, combined with a small application of salt. This is an effective though somewhat laborious method.

Felling, followed by the application of 2½ pounds of salt to the base of the stump of bushes measuring from 1 to 35 square inches in cross section, and of 5 pounds of salt for all larger sizes, was an effective method of eradicating *Rhamnus lanceolata.*

Felling in the fall, followed by an application of kerosene sufficient to cover the crown, killed 52 of the 54 bushes whose area in cross section varied from 1 to 45 square inches.

The rate of lethal effectiveness of salt for *Rhamnus lanceolata* is highest for spring applications and diminishes for successively later applications. Kerosene acts most rapidly in midsummer, and its lethal rates for spring and fall are approximately equal.

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